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An Automated System for an Analog Light-Sensor with Adjustable Measuring Range and High Resolution in WSN

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Abstract

A calibration concept of an analog light-sensor for the use in a dark ambience is presented in this paper. The aim is the automatic detection of an upper and lower sensitivity limit to use the system in combination with a Wireless-Sensor-Node [1] as an impulse generator for industrial strobe beacons. For optimal measuring ranges the gain of the sensor is variable and allows adapted sensor resolutions. A calibration process is presented which focuses on the upper light limit and calculates the lower limit depending on gain and user parameters. A measuring accuracy of around 0.43 lx and a standard deviation of 0.42 lx are achieved. The resolution of the sensor depends on the measuring range and is up to 0.05 lx. An experimental setup shows performances within a specific scenario.

© 2011 Published by Elsevier Ltd. Open access under [CC BY-NC-ND license](https://creativecommons.org/licenses/by-nc-nd/4.0/).*Keywords:* Wireless Sensor Networks; Analog Light-Sensor; Adjustable Measuring Range; Strobe Beacons

1. Introduction

Light intensity measurements becomes more and more important in consumer fields, like backlight control or home automation [2]. Also in security-relevant industrial facilities, sensing of light is indispensable for safety reasons. In this work the focus is set on wind energy plants, which need strobe beacons to show potential hazards in darkness [3].

The problem is that a variety of specifications exists which describes the corresponding thresholds for these beacons in order to start or to stop flashing. This leads to the need of an adaptive calibration system focusing on an upper level and automatically calculating the preset user defined lower limit.

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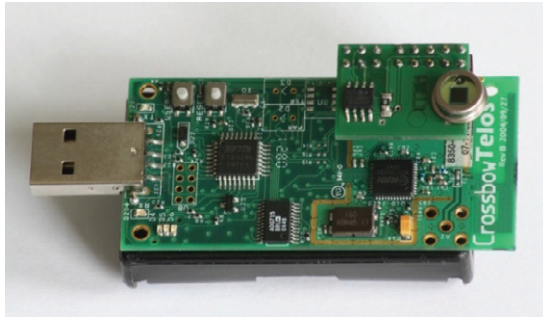


Fig. 1: Telos Rev B with adjustable light-sensor.

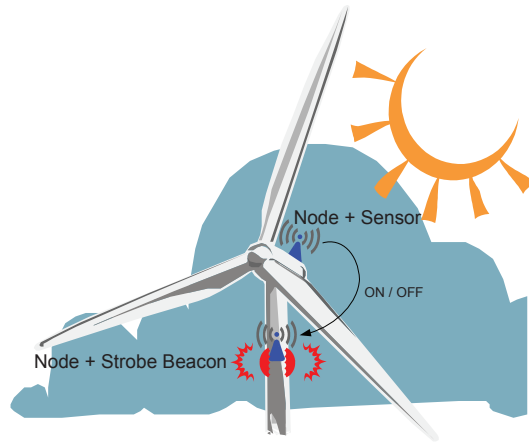


Fig. 2: Application example for use of proposed Sensor-Node.

The principle of sensing is to convert light into current and transform this parameter into a corresponding voltage. An Analog-to-Digital-Converter (ADC) is then used to generate digital data. These digital data can be processed and sent wirelessly with a transmitter to various receivers (Fig.1 and Fig. 2).

2. Calibration and Measurement Technique

In this work the focus is set on automatic and precise detection of an adjustable upper and lower light limit in dark ambience. For this purpose, no commercial digital light-sensor is used, due to the restrictions in resolution and flexibility. We also want to demonstrate how to use the flexibility of an analog sensor in combination with an adjustable amplifier to control the resolution and measuring range.

Because of the integration in a wireless node the resolution of an integrated Microcontroller ADC is limited, just like the computational complexity of the signal processing. In this example we use a 16-Bit MCU and an Analog-to-Digital-Converter with 12-Bit resolution. Because of these restrictions we propose a recursive system that iteratively detects a range in which a preset upper and lower limit can be measured. The hardware consists of a photodiode, an operational amplifier with variable gain G_{OP} , a MCU with integrated ADC and a transceiver. The hardware concept, including the amplification-feedback, is shown in Figure 3.

Generally, ADC-values corresponding to the amplification and to the user constraints of a sensor can be calculated, but due to component-tolerances this calculation will often lead to unacceptable inaccuracies. A calibration is proposed, which focuses on the upper limit and calculates the preset lower limit. For an optimal resolution the calibration process aims to obtain the maximum ADC value corresponding to the upper limit. This approach leads to a high numerical difference between upper and lower ADC value.

The initialization of the calibration procedure starts by loading the user constraints for a requested upper and lower intensity limit in the MCU. In the next step the microcontroller starts the initialization by setting the gain to the minimum achievable value $G_{OP} = G_{min}$. For accurate calibration the ambient light that is sensed by the light-sensor has to be set to the upper limit. This is done by a reference light source which can be precisely adjusted to various values. By automatically and iteratively increasing the gain G_{OP} the calibration attempts to receive a maximum ADC-value for an increased resolution. If this is completed or the maximum amplification is achieved, the calibration for the upper value is completed. In

the last step the ADC-value calculation for lower limits finishes the process by considering the preset user constraints and the operational gain G_{OP} (Figure 4).

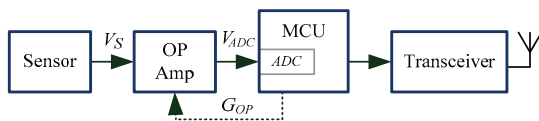


Fig. 3: Block diagram of the recursive system for an iterative calibration system.

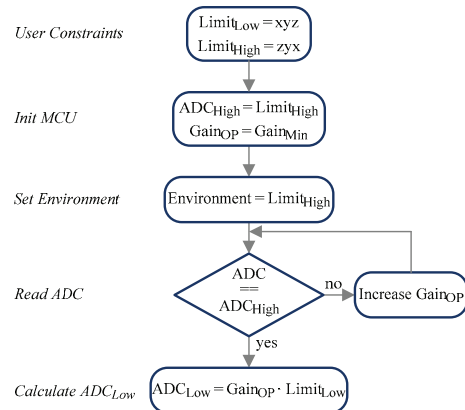


Fig.4: Flow chart of the light-sensor calibration process.

3. Experimental Functionality Test

After the implementation in TinyOS [4] the calibration process is tested in an experimental setup to proof the functionality of our approach. In this setup the focus is set on the calibration procedure and the automatic threshold detection during the run-time of our system. The analysis is shown in Figure 5. The system starts with calibrating and increasing the gain until the upper limit is reached. The calibration is followed by manually testing upper and lower limit which is here fixed to 646 lx and 368 lx. The result shows the detection of the lower limit and the setting of an On-Impulse after about 30 samples. After 40 samples the upper limit is reached and the On-Impulse is cleared. The experimental setup also shows the principle functionality of the upper and lower limit and the negligence of small bursts as shown between samples 50 to 60.

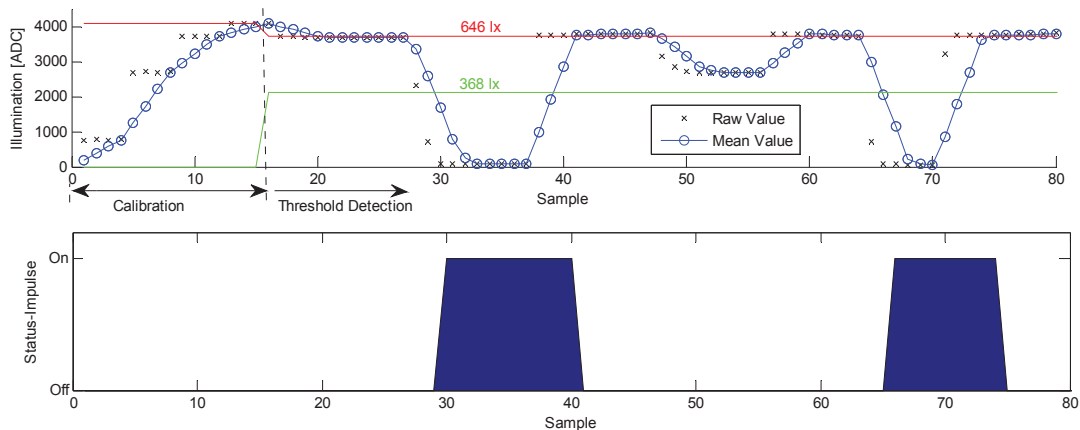


Fig. 5: Experimental setup demonstrating calibration process and setting of an On- and Off-Impulse depending on the Illumination.

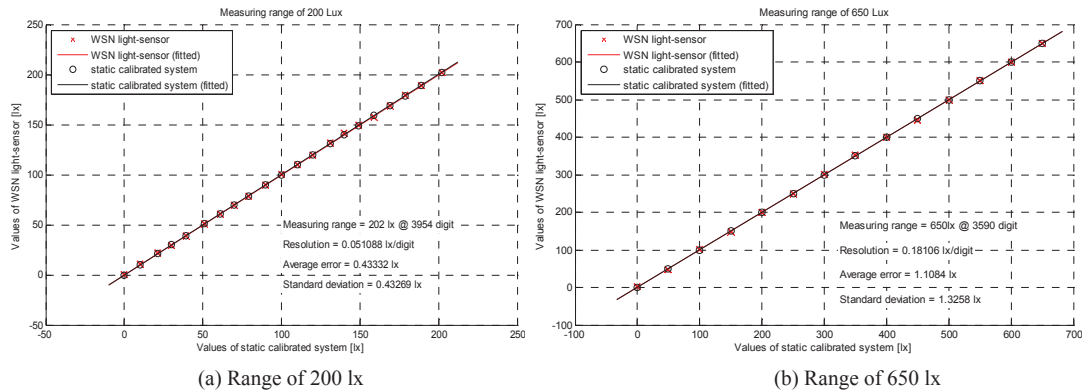


Fig. 6: Measurement results after calibration at range of different values.

4. Measurement Accuracy

The results for measurement ranges with an upper limit of 200 lx and 650 lx are shown in Figure 6a and 6b. In addition to the values measured with the approach presented in this paper, values of a static calibrated system with resolution of 1 lx are plotted. The figures show the accuracy that can be achieved by our calibration procedure in combination with the adaptive hardware. The accuracy decreases for lower values due to the MCU calculation but is still acceptable compared to uncalibrated systems. Finally for our cases the measuring accuracy is up to 0.43 lx for a 200 lx-range. The standard deviation is about 0.42 lx. Furthermore, a high resolution of 0.05 lx is achieved for 200 lx-range and due to the resolution of the ADC 0.18 lx for the 650 lx-range.

5. Conclusion and Future Work

The experimental results show that a high resolution and an adaptive measurement range for dark ambient light is achieved with the proposed approach. A functional test showed the principle concept of our design and the possibility to detect upper and lower limits. In this example the approach is used for light-sensing but the concept can also be used for different sensors like humidity or temperature. Future work will concentrate on the implementation of this approach in a real wind energy plant. This will on the one hand show if the concept will work in real environment and on the other hand will replace the nowadays used cable-driven solutions.

References

- [1] TmoteSky Brochure, Datasheet and Quick Start Guide from <http://www.sentilla.com/moteiv-transition.html>.
- [2] Park H, Burke J, Srivastava M. *Design and implementation of a wireless sensor network for intelligent light control*. Proceedings of the 6th international conference on Information processing in sensor networks, 2007.
- [3] U.S. Department of Transportation. Specification for Obstruction Lighting Equipment, 2009
- [4] Homepage TinyOS <http://tinyos.net>.